

Original Research Article

Effectiveness of anterior guided growth in correction of knee flexion deformity in children with cerebral palsy: a prospective study

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ABSTRACT

Background: Knee flexion deformity is a common and functionally disabling problem in children with cerebral palsy, leading to impaired gait, increased energy expenditure and progressive loss of mobility. Conventional surgical procedures provide correction but are associated with higher morbidity and risk of recurrence. Anterior guided growth (AGG) has emerged as a minimally invasive alternative that utilizes residual growth potential for gradual deformity correction. To evaluate the effectiveness of anterior guided growth in correcting fixed knee flexion deformity in children with cerebral palsy.

Methods: This prospective study included skeletally immature children with cerebral palsy presenting with fixed knee flexion contracture who underwent anterior distal femoral hemiepiphysiodesis. Clinical assessment included measurement of fixed knee flexion contracture (FKFC) and popliteal angle using a goniometer. Radiological evaluation assessed sagittal plane alignment. Measurements were recorded preoperatively and compared with postoperative values at a minimum follow-up of 12 months. Statistical analysis was performed using repeated measures ANOVA and Friedman test.

Results: There was a statistically significant reduction in fixed knee flexion contracture both clinically and radiologically over the follow-up period. The popliteal angle also showed significant improvement, indicating reduction in hamstring tightness. The correction was gradual and sustained, with an average correction rate consistent with growth modulation principles. Complications were minimal and no major implant-related failures were observed.

Conclusions: Anterior guided growth is an effective, safe and minimally invasive technique for the management of moderate knee flexion deformity in children with cerebral palsy. It allows gradual correction with low morbidity and represents a valuable growth-preserving surgical option in appropriately selected patients.

Keywords: Anterior guided growth, Cerebral palsy, Distal femoral hemiepiphysiodesis, Growth modulation, Knee flexion contracture

INTRODUCTION

Cerebral palsy (CP) is the most common cause of physical disability in childhood and comprises a group of permanent disorders affecting movement and posture, attributed to non-progressive disturbances in the developing fetal or infant brain.¹ Children with CP frequently develop secondary musculoskeletal deformities due to spasticity, muscle imbalance, impaired motor

control and altered growth, which significantly impact functional mobility and quality of life.² Among these deformities, knee flexion deformity is one of the most prevalent and functionally limiting abnormalities of the lower limb. It contributes to crouch gait, reduced stride length, increased energy expenditure and progressive deterioration in ambulatory capacity, particularly in children classified under gross motor function classification system (GMFCS) levels I–III.³ The deformity results from a complex interplay of hamstring

spasticity, quadriceps weakness, posterior capsular tightness and progressive bony remodeling of the distal femur.⁴ If left untreated, it can lead to worsening of gait mechanics, early fatigue, pain and eventual loss of independent ambulation.⁵

Management of knee flexion deformity includes both non-operative and operative modalities. Conservative measures such as physiotherapy, orthoses and botulinum toxin injections are useful in early or dynamic deformities but have limited efficacy in established fixed contractures.⁶ Traditional surgical options, including hamstring lengthening and distal femoral extension osteotomy, can provide immediate correction; however, they are associated with increased surgical morbidity, prolonged rehabilitation and risk of recurrence, especially in skeletally immature patients.⁷

In recent years, guided growth techniques have gained popularity as a minimally invasive alternative for the correction of angular and sagittal plane deformities in growing children. AGG of the distal femur, achieved through anterior distal femoral hemiepiphysiodesis, utilizes the principle of growth modulation to gradually correct knee flexion deformity by restraining anterior physal growth while allowing continued posterior growth.⁸ This technique offers several advantages, including minimal surgical trauma, early mobilization, preservation of growth potential and controlled correction with reduced risk of overcorrection.⁹

Previous studies have reported encouraging outcomes with AGG in children with neuromuscular disorders, demonstrating progressive improvement in fixed knee flexion contracture and gait parameters.¹⁰ However, there is limited data regarding its effectiveness in the Indian population, where variations in growth patterns, access to rehabilitation and follow-up compliance may influence outcomes.

Therefore, the present study aims to evaluate the effectiveness of anterior guided growth in correcting knee flexion deformity in children with cerebral palsy by assessing clinical and radiological outcomes over a minimum follow-up period of one year.

METHODS

Study design

This study was conducted as a prospective observational study. The study was designed to evaluate the effectiveness of AGG in correcting knee flexion deformity in children with cerebral palsy using standardized clinical and radiological parameters

Study setting

The study was carried out in the Department of Orthopaedics in Mes Medical College, Perinthalmanna.

The department routinely manages children with cerebral palsy and performs Anterior Guided Growth surgery for knee fixed flexion contractures. All surgeries, follow-up assessments and data collection were conducted at the same institution to ensure uniformity in evaluation and treatment protocols.

Study Population

Skeletally immature children diagnosed with cerebral palsy presenting with fixed knee flexion deformity in northern Kerala were included in the study.

Study duration

The study period extended from 1 April 2024 to 31 December 2025 for prospective cases. Each patient was followed up for a minimum duration of one year.

Inclusion criteria

Children with Cerebral palsy presenting with moderate knee flexion contracture (10-30 degrees) after 7 years of age and before skeletal maturity, with minimum 2 years of growth remaining.

Gross Motor Function Classification Scale (GMFCS) I, II or III

Exclusion criteria

Severe flexion deformity of knee (>30 degrees) requiring corrective osteotomy, loss to follow-up, infection around the knee joint, any prior soft tissue or bony surgery in the last 6 months and those who are not willing

Study sampling

A convenience sampling technique was employed. All worthy children presenting throughout the study period were enrolled until the required sample size was achieved.

Study sample size

The sample size was calculated based on the expected difference in mean fixed knee flexion contracture (FKFC) before and after AGG using the formula for paired comparison.

Sample size (n)

$$n = \frac{(z_{1-\alpha/2} + z_{\beta})^2 \cdot \Delta^2}{(z_{1-\alpha/2} + z_{\beta})^2 \cdot \Delta^2}$$

$$\Delta = \frac{(x_1 - x_2) - ((s_1^2 - s_2^2))}{(s_1^2 + s_2^2)}$$

x1 indicates mean fixed knee flexion contracture (FKFC) before AGG and s1 is the corresponding standard

deviation. x_2 indicates mean FKFC post AGG during followup and s_2 is the corresponding standard deviation, "where" $\left[\frac{z}{\sqrt{1-\alpha/2}} \right] = 1.96$ for $\alpha = 5\%$, $z\beta = 0.842$ for $\beta = 20\%$, $x_1 = 13$, $x_2 = 5$, $S_1 = 5$, $S_2 = 7$, $n = 6.356$, Sample size = 7.⁸

Preoperative assessment

All patients underwent detailed clinical and radiological evaluation.

Clinical assessment

Fixed knee flexion contracture (FKFC) was measured using a standard goniometer with the patient in the supine position and the hip in extension, knee in maximum possible extension and ankle in plantar flexion using a goniometer.

Popliteal angle was measured with the hip flexed to 90° and the knee passively extended until resistance was encountered and angle was measured with the vertical using a goniometer.

Radiological assessment

Lateral radiographs of the knee were obtained in maximum possible extension.

The knee flexion angle was measured as the angle between the anatomical axes of the femur and tibia.

Baseline demographic data, type of cerebral palsy and GMFCS level were recorded.

Surgical technique

All patients underwent anterior distal femoral hemiepiphysiodesis under general anesthesia. With the patient in the supine position, the distal femoral physis was identified under fluoroscopic guidance. Through 2 small anterior incisions, 8 plates with screws were placed across the anterior aspect of the distal femoral physis on both medial and lateral sides, ensuring proper positioning without violating the physis. Care was taken to achieve symmetrical placement to avoid coronal plane deformity.

Postoperative protocol and follow-up

Patients were allowed early mobilization and weight bearing as tolerated. Regular follow-up was performed at periodic intervals, with clinical and radiological assessments conducted at 3 months, 6 months and 12 months. Outcome measurements, including FKFC, popliteal angle and radiological knee flexion angle, were recorded preoperatively and at a minimum follow-up of 12 months.

Outcome measures primary outcome

Change in fixed knee flexion contracture (FKFC).

Secondary outcomes

Change in radiological knee flexion angle, Change in popliteal angle, Rate of deformity correction, Complications and need for re-intervention, Time-based changes at follow-up intervals of 3 months, 6 months and 1 year

Statistical analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS) software. Continuous variables were expressed as mean±standard deviation.

Repeated measures analysis of variance (ANOVA) was used to compare changes in clinical parameters over time, friedman test was used for non-parametric data, bonferroni post hoc analysis was applied for pairwise comparisons. A p value < 0.05 was considered statistically significant.

Data analysis

All collected data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) version 26. Continuous variables such as FKFC and popliteal angle were expressed as mean±standard deviation. Preoperative and postoperative values were compared using the paired t-test. Qualitative variables were expressed as proportions. A p-value of < 0.05 was considered statistically significant.

Ethical considerations

Ethical clearance was obtained from the Institutional Ethics Committee prior to commencement of the study. Informed written consent from parents and assent from children were obtained. Confidentiality of patient data was maintained throughout the study and all procedures were performed in accordance with the Declaration of Helsinki.

RESULTS

Clinical outcomes

There was a progressive and statistically significant reduction in clinical fixed knee flexion contracture over time. Mean FKFC improved from $18.14 \pm 3.44^\circ$ preoperatively to $10.14 \pm 3.53^\circ$ at 12 months, Mean correction: 8.00° . Repeated measures analysis (ANOVA) demonstrated a highly significant effect of time on FKFC ($p < 0.001$).

Radiological outcomes

Radiological measurements showed a similar trend of improvement. Mean radiological FKFC decreased from $17.00 \pm 3.22^\circ$ to $9.29 \pm 3.04^\circ$ and mean correction: 7.71° . This reduction was statistically significant ($p < 0.001$).

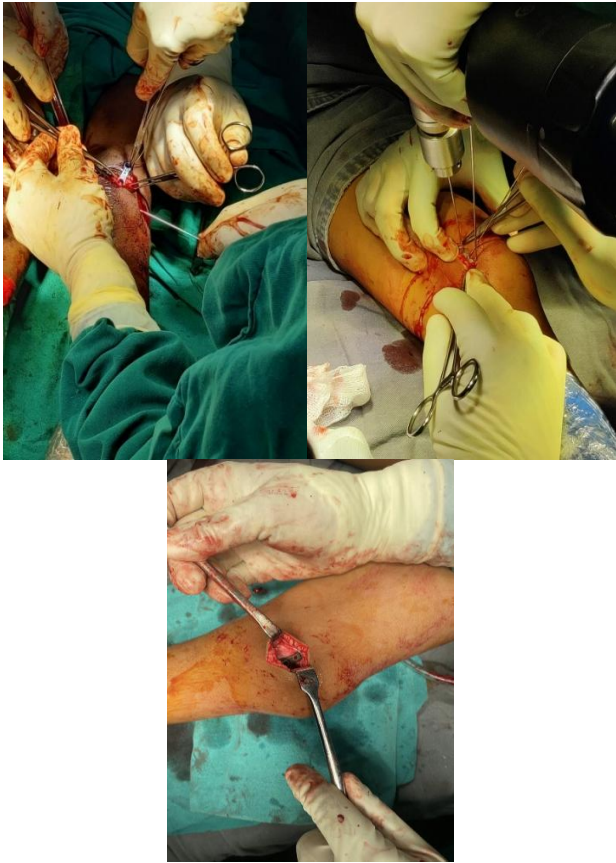


Figure 1 (A-C): Intraoperative surgical images.

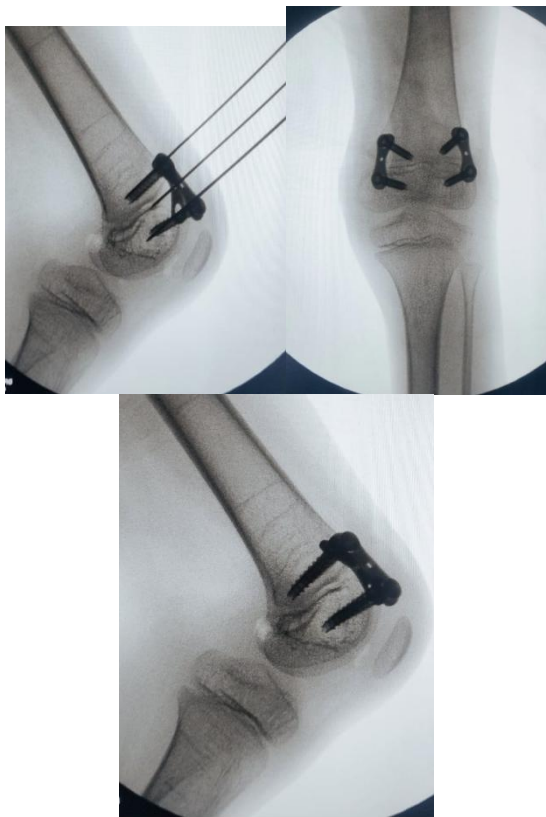


Figure 2 (A-C): Intraoperative C arm images postoperative protocol and follow up.



Figure 3: Post op X-ray 3 months.



Figure 4: Post op X-ray 6 months.



Figure 5: Post op X-ray 12 months.

Popliteal angle

A significant reduction in popliteal angle was observed, indicating improvement in hamstring tightness. Mean popliteal angle decreased from $49.29 \pm 5.09^\circ$ to $33.86 \pm 5.40^\circ$. Mean reduction: 15.43° . This change was statistically significant ($p < 0.001$).

Trend analysis

Repeated measures ANOVA demonstrated a statistically significant reduction across all follow-up intervals for: Clinical FKFC ($p < 0.001$), Radiological FKFC ($p < 0.001$), Popliteal angle ($p < 0.001$). Post hoc analysis confirmed that each follow-up interval showed significant improvement compared to baseline.

Correction rate

The average correction rate of knee flexion deformity following AGG was approximately: 0.67° per month (clinical), 0.64° per month (radiological)

Complications

Two patients (28.6%) developed superficial surgical site infections, which resolved with oral antibiotics. No major complications, implant failures or reoperations were observed.

Table 1: Demographic data.

Characteristic	Value
Number of patients	7
Total number of knees	13
Mean age $\pm$ SD (years)	10.3 ± 1.6
Age range (in years)	8–12
Sex	
Male	6
Female	1
Cerebral palsy subtype	
Spastic diplegia	4
Spastic quadriplegia	2
GMFCS level	
Level II	2
Level III	4
Distribution of knee involvement	
Bilateral	6
Unilateral	1

Table 2: Mean $\pm$ SD of outcome parameters over time.

Time point	Clinical FKFC ($^\circ$)	Radiological FKFC ($^\circ$)	Popliteal Angle ($^\circ$)
Preoperative	18.14 ± 3.44	17.00 ± 3.22	49.29 ± 5.09
3 months	15.86 ± 3.44	15.00 ± 3.22	44.71 ± 7.52
6 months	13.71 ± 3.50	12.86 ± 3.29	38.57 ± 5.16
12 months	10.14 ± 3.53	9.29 ± 3.04	33.86 ± 5.40

Table 3: Preoperative vs 12-month comparison.

Parameter	Preoperative (Mean±SD)	12 months (Mean±SD)	Mean change	P value
Clinical FKFC (°)	18.14±3.44	10.14±3.53	8.00	<0.001
Radiological FKFC (°)	17.00±3.22	9.29±3.04	7.71	<0.001
Popliteal Angle (°)	49.29±5.09	33.86±5.40	15.43	<0.001

Table 4: Complications.

Complication	Number (%)
None	5 (71.4%)
Superficial infection	2 (28.6%)
Deep infection	0
Implant failure	0
Reoperation	0

DISCUSSION

Knee flexion deformity is a key determinant of functional limitation in children with cerebral palsy, contributing significantly to crouch gait, increased energy expenditure and progressive deterioration in mobility.¹¹ In the present study, AGG resulted in a statistically significant and progressive correction of FKFC, along with improvement in radiological alignment and popliteal angle, highlighting its effectiveness as a growth modulation technique.

Rethlefsen et al demonstrated significant improvement in knee extension following anterior distal femoral hemiepiphysiodesis, with predictable correction rates in skeletally immature patients.¹² Similarly, studies on guided growth techniques have emphasized the reliability of physal modulation in achieving gradual deformity correction while preserving normal growth potential.¹³ The mean clinical correction of 8° and radiological correction of 7.71° observed in this study are consistent with previously reported outcomes.

The gradual nature of correction observed in the study is a major advantage of AGG. Unlike distal femoral extension osteotomy, which provides acute correction but is associated with higher morbidity, AGG allows progressive realignment, minimizing soft tissue trauma and enabling better neuromuscular adaptation.¹⁴ This is particularly important in children with cerebral palsy, where abrupt biomechanical changes may negatively impact motor control and gait patterns.

In previous studies, there was an improvement in muscle balance was noted following correction of underlying skeletal deformity.¹⁵ An important finding in the present study was the significant reduction in popliteal angle (mean reduction: 15.43°), indicating improvement in hamstring tightness. Although AGG primarily addresses the osseous component of deformity, this observation suggests that correction of sagittal alignment may facilitate secondary soft tissue adaptation.

The correction rate observed in this study (approximately 0.65° per month) is comparable to rates reported in the literature, which typically range between 0.5° and 1° per month.^{12,16} This predictable rate of correction allows for better planning and timing of intervention, especially in growing children with sufficient remaining physal activity.

The complication rate in the present study was low, with only 28.6% of patients developing superficial infections, all of which resolved with conservative management. No major complications, implant failures or need for reoperation were observed. This is consistent with existing literature, which describes AGG as a relatively safe procedure with minimal complications.¹⁷ Compared to osteotomies, which carry risks of neurovascular injury, nonunion and prolonged immobilization, AGG offers a significantly safer alternative with early mobilization and reduced hospital stay. Another important advantage of AGG is its reversibility. Implant removal after achieving desired correction allows resumption of normal physal growth, reducing the risk of overcorrection. However, rebound deformity remains a potential concern, particularly in younger patients with significant remaining growth.¹⁸ Although no cases of overcorrection were observed in this study, longer follow-up is required to assess the risk of recurrence.

Despite these advantages, AGG has certain limitations. Its effectiveness is dependent on adequate remaining growth, making it less suitable for patients nearing skeletal maturity. Additionally, severe deformities with significant capsular contracture or advanced bony changes may not respond adequately to guided growth alone and may require adjunctive procedures such as hamstring lengthening or osteotomy.¹⁹ Therefore, careful patient selection is crucial for optimal outcomes.

Limitations

The present study has certain limitations. The sample size was small and the follow-up period was limited to one year. Furthermore, objective gait analysis was not performed,

which could have provided additional insight into functional improvement. However, the prospective design and consistent follow-up strengthen the validity of the findings.

The primary limitation of this study is its small sample size, which restricts the generalizability of the findings and limits the ability to perform subgroup analyses based on cerebral palsy subtype, Gross Motor Function Classification System (GMFCS) level or baseline severity of deformity. Consequently, outcome measures such as complication rates are highly sensitive to individual events and should be interpreted with caution.

The absence of a control or comparison group limits causal inference, making it difficult to distinguish the effects of anterior guided growth from those of concurrent rehabilitation, normal skeletal growth or other non-operative interventions. In addition, the follow-up period of 12 months was sufficient to evaluate early and intermediate correction but was inadequate to assess long-term maintenance of correction, recurrence following implant removal, overcorrection or late implant-related complications.

Functional outcomes were not assessed using validated objective measures such as instrumented gait analysis, functional mobility scales or quality-of-life questionnaires. Therefore, although significant radiographic correction was demonstrated, its translation into functional improvement could not be objectively quantified.

Radiographic measurements may also have been influenced by variability in patient positioning and imaging technique despite standardized assessment protocols, particularly in children with spasticity. Furthermore, the limited sample size precluded analysis of factors predicting correction, recurrence or treatment failure, thereby limiting guidance for patient selection. Finally, because the study cohort included children with varying cerebral palsy patterns and associated multilevel deformities, residual confounding may exist and the isolated effect of knee-focused guided growth cannot be completely separated from the broader biomechanical influences of the underlying condition.

CONCLUSION

Anterior guided growth is an effective, safe and minimally invasive technique for the correction of moderate knee flexion deformity in skeletally immature children with cerebral palsy. It provides gradual and predictable correction of deformity, with significant improvement in both clinical and radiological parameters, as well as reduction in hamstring tightness.

The procedure is associated with low complication rates, allows early mobilization and preserves growth potential, making it a favorable alternative to more invasive procedures such as distal femoral extension osteotomy.

Optimal outcomes are achieved with appropriate patient selection, adequate remaining growth and regular follow-up.

Anterior guided growth should be considered a valuable treatment option in the management of knee flexion deformity in children with cerebral palsy, particularly in those with moderate deformity and sufficient growth potential.

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Conflict of interest: None declared

Ethical approval: The study was approved by the Institutional Ethics Committee

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